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The Possible Suppression of Natural Ionospheric Irregularities with Artificial Plasma Injection

Keith M. Groves*[1], Ronald G. Caton[2] and John M. Retterer[1]

[1] Boston College, ISR, 140 Commonwealth Ave, Chestnut Hill, MA USA
(E-mail: keith.groves@bc.edu, john.retterer@bc.edu)

, [2] AFRL/RVB, Kirtland AFB, NM, USA

ABSTRACT

The Air Force Research Laboratory created artificial ionized clouds in the upper atmosphere by releasing metal vapor from two NASA-launched sounding rockets at Kwajalein Atoll in May 2013. The purpose of the releases was primarily to characterize the generation and evolution of samarium metal ions in near-earth space, but a secondary motivation was to test the potential for suppressing natural irregularities associated with equatorial Spread F. The releases occurred at dusk and over a period of minutes the layers expanded to approximately 15 kilometers in radius and persisted for at least 90 minutes as observed by the ALTAIR incoherent scatter radar.

The possibility of using metal vapor to create artificial plasmas in space was first recognized many years ago and the concept has been successfully demonstrated many times for a variety of purposes using in situ releases of metal atoms in the ionosphere [see, e.g., Davis, 1979; Heppner et al., 1982; Larsen et al., 2002]. Certain metals, such as barium, ionize only in the presence of sunlight (photo-ionization) while others, such as samarium, lanthanum and neodymium, can also form ions through an exothermic reaction in the presence of oxygen (chemi-ionization). This chemi-ionization process enables such metals to form artificial plasma clouds both day and night. Chemical releases of samarium in the upper atmosphere have been conducted before. Two such releases were performed at high latitudes, but in neither case were radio frequency diagnostics applied to measure either ionization levels or propagation effects. A primary motivation for the Metal Oxide Space Cloud (MOSC) experiment was the suppression of equatorial electron density irregularities responsible for radio wave scintillation. In the case of the 2nd release on 9 May, the cloud remained nearly stationary and was observed by the ALTAIR radar for more than one hour after the release. The radar provided detailed information on the state of the equatorial ionosphere throughout the experiment.

Figure 1 shows a range-time-intensity (RTI) plot from ALTAIR for the May 9 release which illustrates the observations nicely. Between 100 and 200 seconds the rocket can be observed in the radar sidelobes at altitudes between 50 and 170 km. The receiver is seen to saturate (range-extended white false color radar echo) as the rocket enters the main beam and releases the samarium vapor. The radar then detects the thin plasma cloud that forms and gradually expands as the samarium ionizes. Later in the evening spread F structures with associated irregularities were observed to form to the west of the samarium cloud location, drifting eastward while the cloud remained relatively stationary. In the presentation we will examine the potential interaction of the diffuse bottomside cloud with the overlying F region plasma and discuss a possible mechanism for depleting small-scale irregularities that may impact radio wave propagation in the ionosphere.

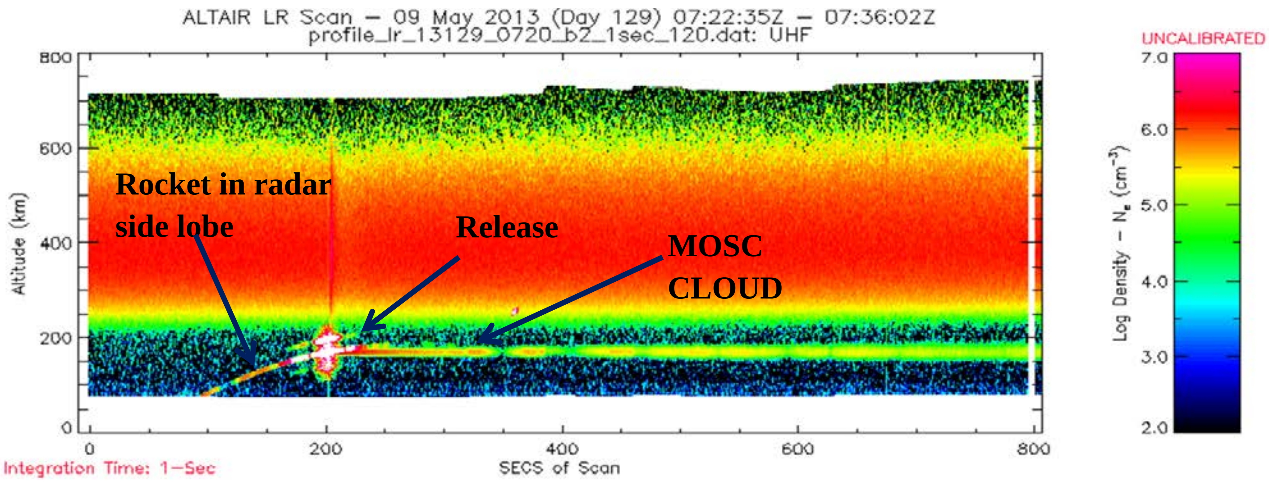

Figure 1. Early-time ALTAIR UHF radar measurements of the second MOSC samarium release. The plots show radar power as a function of altitude and time (range-time-intensity), including sidelobe detection of the rocket ascending, receiver saturation when the rocket flew through the main beam at release point, and the subsequent signature of the cloud. Variations in cloud density after the first two minutes are due primarily to scanning the beam across the cloud.

Key words: Irregularity suppression, scintillation, ionosphere, artificial plasma.

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